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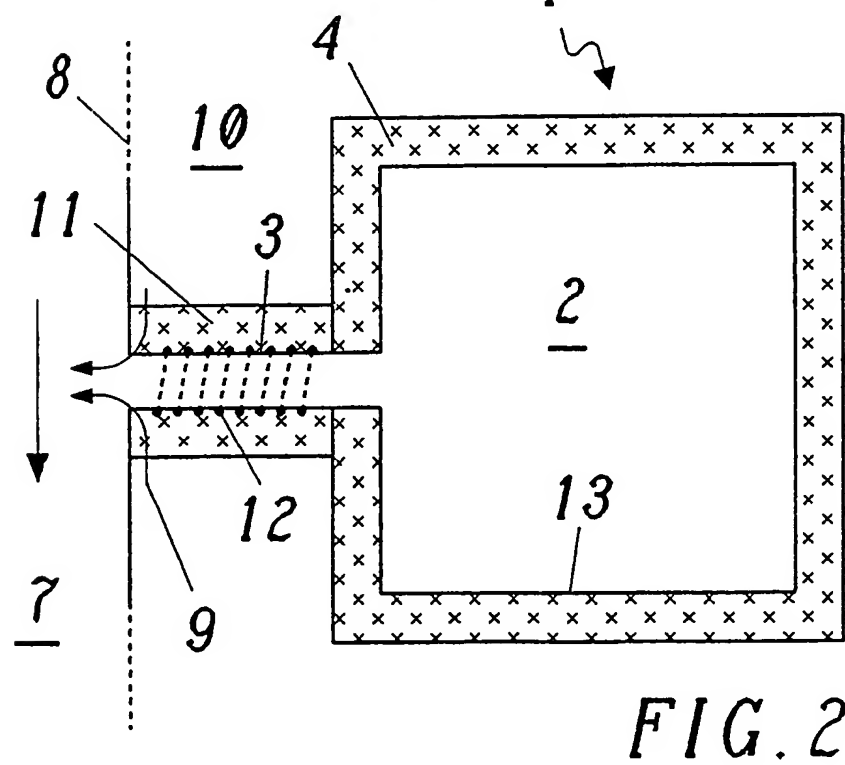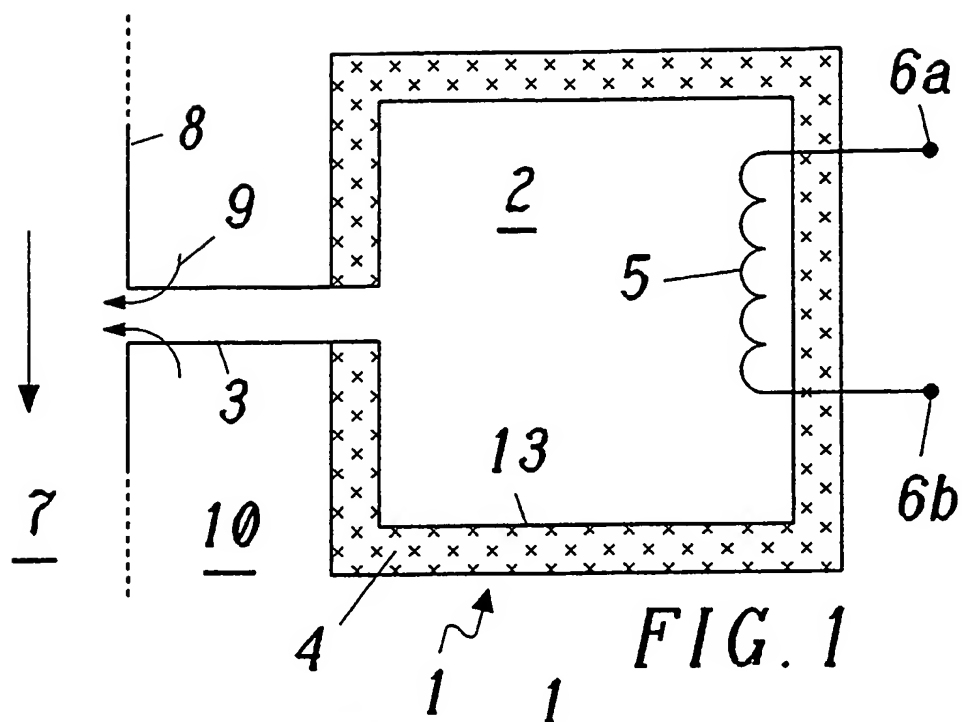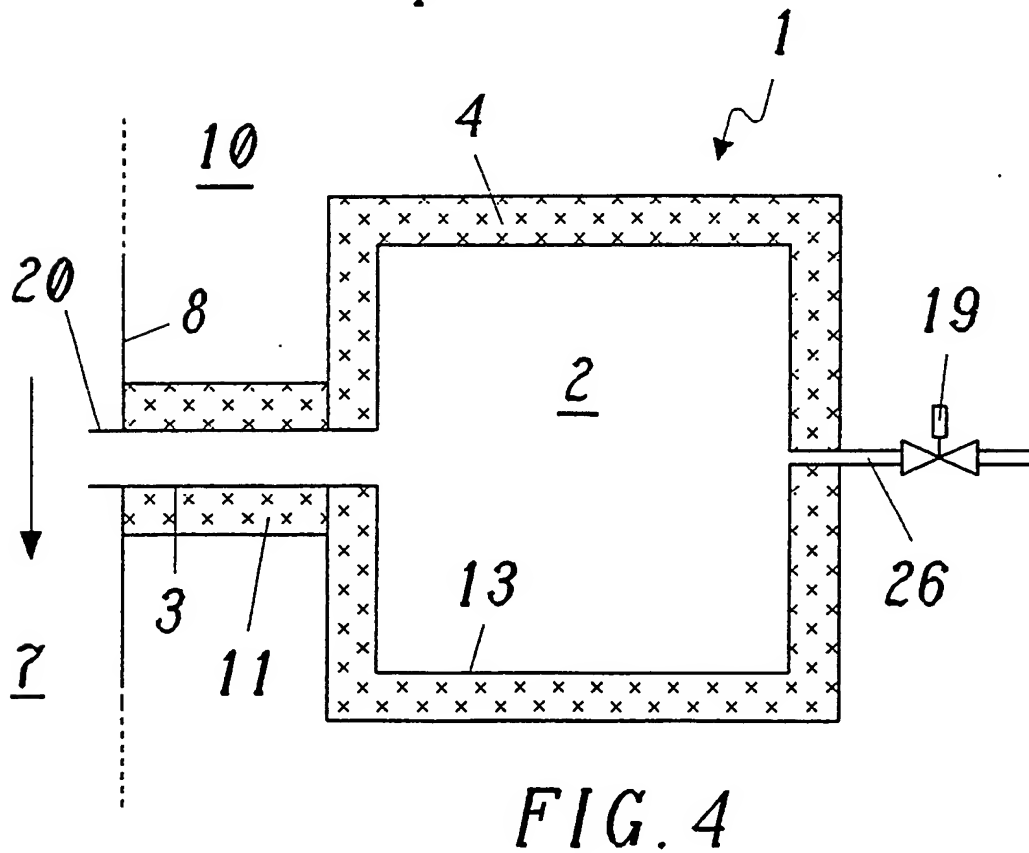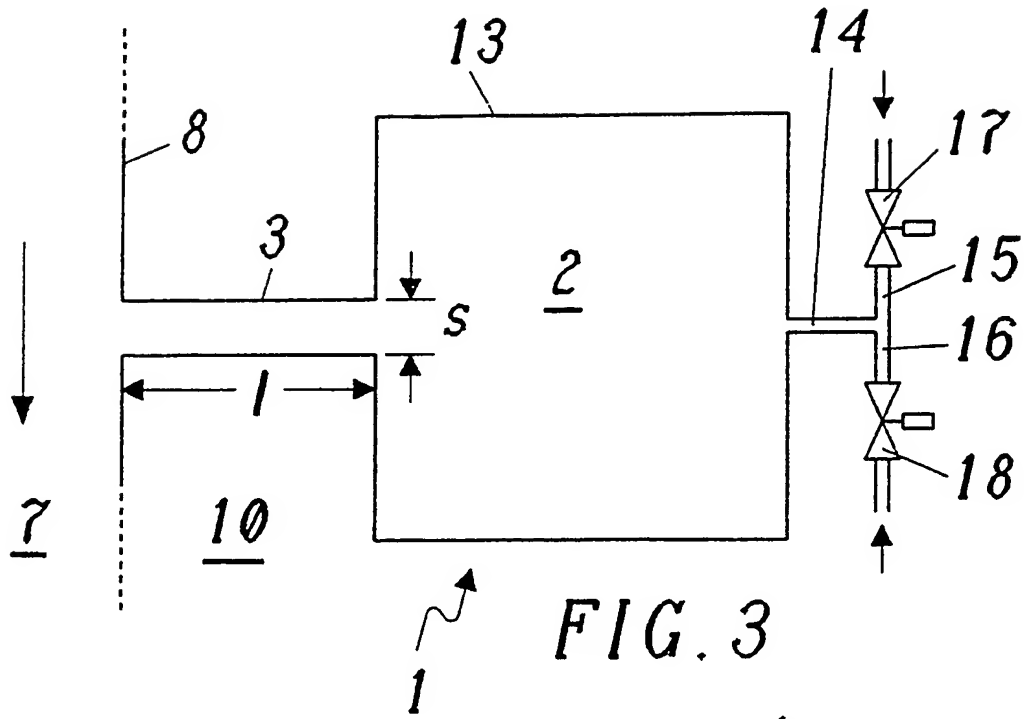INT CL^6 F23M 13/00
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(54) Apparatus for damping thermoacoustic vibrations in combustion chamber
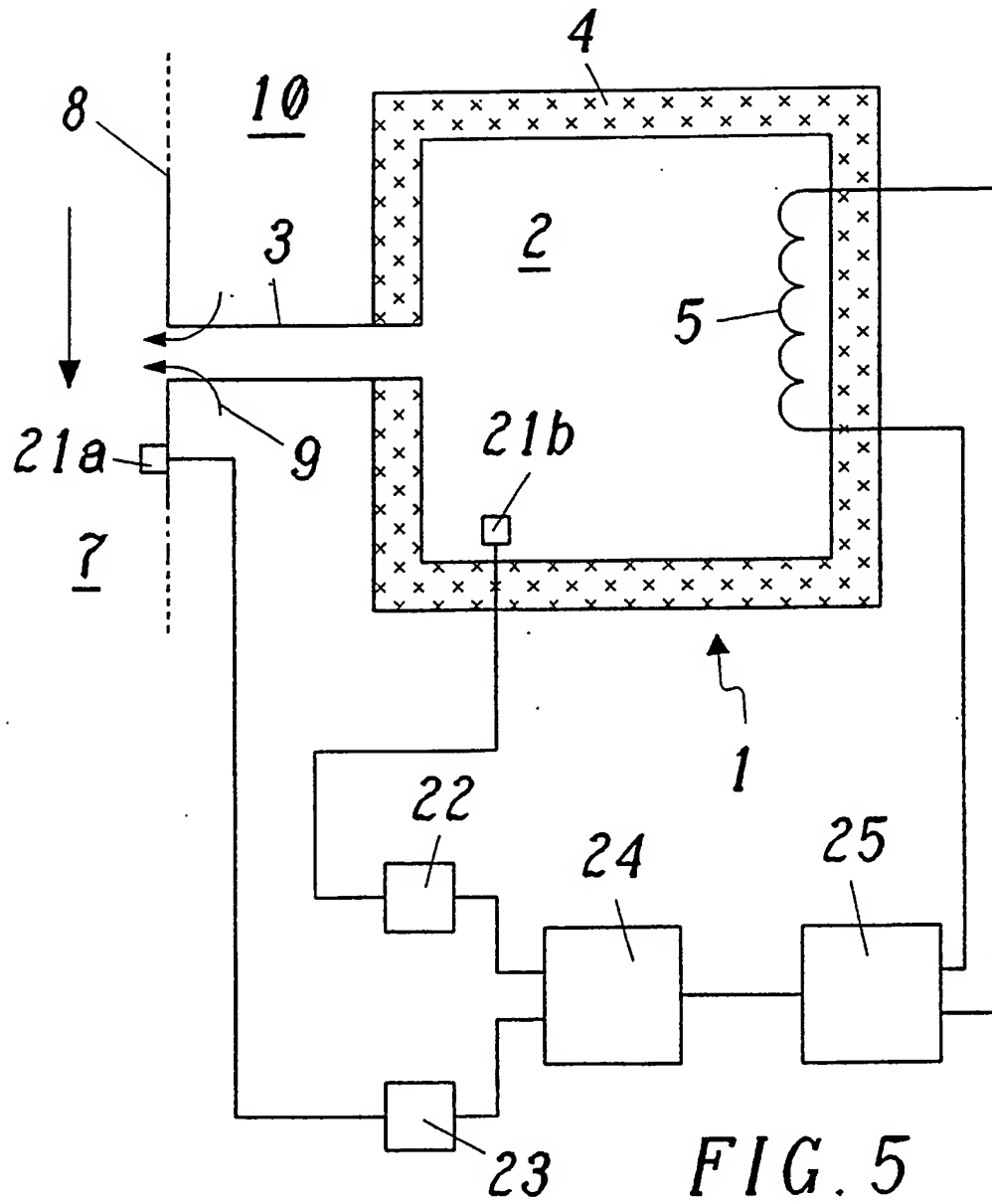
(57) Apparatus for damping thermoacoustic vibrations in a combustion chamber (7), in particular in the combustion chamber of a gas turbine, comprises a Helmholtz resonator (1) having a resonator space (2) and a connecting tube (3) by means of which the resonator space (2) is connected to the combustion chamber (7), a uniform damping performance is achieved even under fluctuating operating conditions when the Helmholtz resonator (1) is equipped with means for controlling the resonator frequency as a function of the frequency of the combustion-chamber vibrations. This may involve controlling the density of the gases in the connecting tube by heating them. Alternatively, a gas feed line leads into the resonator space so that gases of different density can be directed into the resonator space. A control circuit may control the density of the gases in the connecting tube in accordance with the phase difference between the combustion chamber vibrations and the resonator vibrations.

FIG. 1

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FIG.1

FIG.2

FIG.3

FIG.4

FIG.5
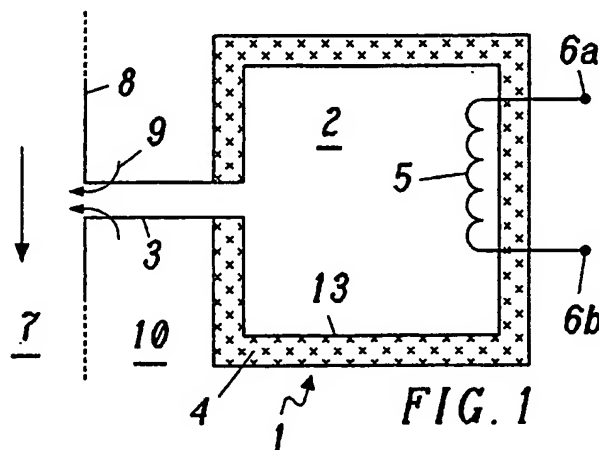
APPARATUS FOR DAMPING THERMOACOUSTIC VIBRATIONS IN A COMBUSTION CHAMBER

5

TECHNICAL FIELD

The present invention relates to the field of combustion technology. It relates to an apparatus for damping thermoacoustic vibrations in a combustion cham-
10 ber, in particular in the combustion chamber of a gas turbine, comprising a Helmholtz resonator having a resonator space and a connecting tube by means of which the resonator space is connected to the combustion chamber.

15 Publication EP-A1-0 577 862, for example, discloses such an apparatus.

PRIOR ART

In combustion chambers, as used in particular
20 in gas turbines, thermoacoustic vibrations are excited by an amplifying interaction between thermal and acoustic disturbances. Undesirably high vibration amplitudes can appear in the process if acoustic natural vibrations of the combustion chamber are
25 excited. The adverse consequences are inadmissably high mechanical loading of the combustion chamber, a rise in the emissions through inhomogeneous combustion and, in the extreme case, extinguishing of the flame. This problem is intensified in modern combustion chambers,
30 since cooling-air openings in the combustion chamber which would dampen the pressure pulsations are as far as possible dispensed with.

In gas-turbine combustion chambers, depending on the size of the combustion chamber, a narrow-band
35 excitation of high amplitude in the frequency range of 100 to 250 Hz typically occurs. This excitation can be dampened by means of so-called Helmholtz resonators, the frequency of the Helmholtz resonator having to be accurately coordinated with the frequency of the
40 combustion-chamber vibration. In connection with an

afterburner for a gas turbine, it has already been proposed in the publication mentioned at the beginning to use such a Helmholtz resonator for this purpose.

But experience now shows that, depending on
5 the operating conditions (full load/partial load, ambient temperature, fuel/air ratio, gas or oil operation, etc.), the combustion-chamber frequency can vary by up to ± 20%. On the other hand, the frequency in the Helmholtz resonator is also dependent upon the
10 operating conditions: experimental tests have shown that the Helmholtz frequency can be displaced during rising pulsation amplitudes by up to 19% towards lower values. But it is known that the damping performance is massively reduced by only slight differences between
15 the two frequencies.

SUMMARY OF THE INVENTION

The object of the invention, then, is to specify a damping apparatus having a Helmholtz
20 resonator, by means of which damping apparatus a uniform damping performance can be achieved even under fluctuating operating conditions.

This object is achieved in an apparatus of the type mentioned at the beginning when the Helmholtz
25 resonator is equipped with first means for controlling the resonator frequency as a function of the frequency of the combustion-chamber vibrations.

The essence of the invention therefore consists in designing the apparatus in such a way that
30 the resonator frequency is appropriately readjusted during a change in the frequency of the vibration to be dampened.

The readjustment of the resonator can be effected in different ways. In a first preferred
35 embodiment of the apparatus according to the invention, the first means comprise second means for controlling the density of the gases located in the connecting tube. This enables the frequency of the resonator to be

changed in a simple manner without a (mechanically complicated) change in the resonator volume.

The control can be realized in an especially simple manner when, in a second preferred embodiment, the second means control the density of the gases located in the connecting tube by changing the temperature.

A first advantageous embodiment of the temperature control is characterized in that the second means comprise an electric heating element by which the gases located in the resonator space can be heated.

A second advantageous embodiment of the temperature control is distinguished by the fact that the second means comprise an electric heating element by which the gases located in the connecting tube can be heated.

A third advantageous embodiment of the temperature control is characterized in that the second means comprise a scavenging-air feed line which leads into the resonator space and by means of which scavenging air can be directed through the resonator space. The temperature in the resonator space can be specifically lowered relative to the combustion chamber by the (relatively cold) scavenging air in order to stabilize frequency differences.

A further embodiment of the apparatus according to the invention is distinguished by the fact that the second means comprise a gas feed line which leads into the resonator space and by means of which gases of different density can be directed alternatively into the resonator space. In this way, the resonance frequency can be changed by changing the average density in a gas mixture of different composition.

Further embodiments follow from the dependent claims.

BRIEF DESCRIPTION OF THE FIGURES

The invention is to be described in more detail below with reference to exemplary embodiments in connection with the drawing, in which:

5   Fig. 1   shows in schematic representation a first exemplary embodiment of an apparatus according to the invention having a heatable resonator space;

      Fig. 2   shows in schematic representation a second

10   exemplary embodiment of an apparatus according to the invention having a heatable connecting tube;

      Fig. 3   shows in schematic representation a third exemplary embodiment of an apparatus accor

15   ding to the invention having a device for feeding auxiliary gases of a different density;

      Fig. 4   shows in schematic representation a fourth exemplary embodiment of an apparatus accor

20   ding to the invention having a device for feeding scavenging air; and

      Fig. 5   shows in schematic representation apparatus according to Fig. 1 in combination with a complete control system.

25

The essence of the invention is to provide a Helmholtz resonator which can be controlled with simple means and the frequency of which can be accurately

30 regulated to the combustion-chamber vibration frequency in all operating states. The frequency of the Helmholtz resonator is described by the following generalized equation:

$$\omega = c_{II}\sqrt{\frac{s \cdot \rho_{II}}{l \cdot \rho_{III} \cdot V}}$$

35

where: ω = Helmholtz-resonator frequency

          c_{II} = sound velocity in the resonator

          s   = cross-sectional area of the connecting tube

l = length of the connecting tube

ρ_{III} = air density in the connecting tube

V = resonator volume

ρ_{II} = air density in the resonator

5   The Helmholtz frequency ω can now be detuned in various ways in accordance with the combustion-chamber frequency. A first exemplary embodiment for an apparatus having controllable resonator frequency is schematically shown in Fig. 1. A Helmholtz resonator 1

10   is shown which comprises a resonator space 2 enclosed by a resonator wall 13 and having the resonator volume V. The resonator space 2 is connected via a connecting tube 3 (length l; cross-sectional area s; see Fig. 3) to a combustion chamber 7 which in turn is defined by a

15   combustion-chamber wall 8.

      The detuning of the resonator is effected here by increasing the temperature in the resonator space 2 by means of a controlled (electric) heating element 5 which is either attached directly in the gas

20   volume or heats up the gas volume via the resonator wall 13. An increase in the temperature by 10% from, for example, 600°K to 660°K reduces the density ρ_{III} by 10% and thus (according to the abovementioned formula) increases the resonator frequency by 5%.

25   It is advantageous in this case to insulate thermally at least the resonator space 2 by means of thermal insulation 4. Furthermore, it is advantageous to blow shielding air 9 from outside (e.g. from the plenum 10 of a gas turbine) into the connecting tube 3

30   to prevent the ingress of hot gases from the combustion chamber 7 into the resonator space 2. The requisite heating output which has to be applied to the terminals 6a,b of the heating element 5 can thereby be reduced to a minimum.

35   A second possibility of detuning the resonator by temperature change is shown in the exemplary embodiment in Fig. 2. Here, the gas in the connecting tube 3 to the combustion chamber 7 is heated with a heating element 12 and thus the gas density is

reduced directly in the connecting tube 3. The heating element 12 can be, for example, a heater winding wound around the connecting tube 3. Here, too, the requisite heating output can be minimized by the connecting tube

5   3 being surrounded in a primary manner with thermal insulation 11 and by the resonator space 2 also being surrounded in a secondary manner with thermal insulation 4. The feeding of shielding air 9 can also be provided as in Fig. 1.

10   A third possibility of detuning the resonator by temperature change is reproduced in the exemplary embodiment in Fig. 4. Via a scavenging-air feed line 26 equipped with a control valve 19, (cool) scavenging air is sent here in a controlled manner through the

15 Helmholtz resonator 1 and thus the temperature in the resonator is influenced. At a small scavenging-air quantity, the air is heated in the resonator space 2 from the hot-gas side (i.e. from the combustion chamber 7). At a high scavenging-air quantity, the air in the

20 resonator space 2 cools down accordingly. It is also advantageous in this case if the Helmholtz resonator 1 together with connecting tube 3 is surrounded with thermal insulation 4 and 11 respectively. The air in the resonator space 2 can thereby be heated to a higher

25 temperature if this is necessary. Furthermore, it is advantageous if the connecting tube 3 projects with a tube piece 20 slightly into the combustion chamber 7 so that the thermal coupling of the resonator to the combustion chamber 7 is improved. This assists the

30 heating of the air in the resonator space.

    A further possibility of detuning the resonator is shown in the exemplary embodiment in Fig. 3. The frequency is detuned here by adding a gas of higher density (e.g. CO_2) or lower density (e.g.

35 helium) into the resonator space 2. Here, too, the sound velocity is varied via a density change; but the density change is not based on the temperature change in a gas but on the change in the mixture ratio of gases of various density. For this purpose, at least

one gas feed line 14 is attached to the resonator space
2, through which gas feed line 14 the auxiliary gases
can be fed. If two branches 15, 16 having one control
valve 17, 18 each are provided at the gas feed line 14,

5   via which branches 15, 16 a gas of higher and lower
density can be added simultaneously in a controlled
manner, frequency changes at the resonator in both
directions can easily be achieved.

        The phase angle (the phase difference)

10   between the pressure vibration in the combustion
chamber 7 and that in the resonator space 2 is the most
suitable control variable for the frequency control, in
which case:

$$\phi = -90° \quad\text{for}\quad f_{BK} = f_{RE}$$

15
$$\phi < -90° \quad\text{for}\quad f_{BK} > f_{RE}$$

$$\phi > -90° \quad\text{for}\quad f_{BK} < f_{RE}$$

where f_{BK} = combustion-chamber frequency, f_{RE} = resonator frequency, and ϕ = phase angle.

20   The phase angle reacts very sensitively to
frequency differences and is therefore the most
suitable control variable for the heating output or
scavenging-air or auxiliary-gas supply. A corresponding
complete control system for an arrangement from Fig. 1

25   is reproduced in Fig. 5. To record the pressure
vibrations, in each case at least one pressure sensor
21a and 21b respectively is arranged at a suitable
point in the combustion chamber 7 and in the resonator
space 2. The measuring signals from the pressure

30   sensors 21a,b are processed in downstream measuring
transducers 22, 23 and transmitted to the two inputs of
a phase comparator 24 which derives a control signal
from the phase difference and delivers it to a
following activating unit 25. The activating unit 25

35   contains a power part which controls the heating output
in the heating element 5. In the examples from Figs. 2
to 4, the heating element 12 and the control valves 17
to 19 respectively are accordingly connected to the
activating unit 25.

The invention results overall in a simple and functionally reliable apparatus for damping the thermoacoustic vibrations in combustion chambers even under fluctuating operating conditions.

PATENT CLAIMS

1. Apparatus for damping thermoacoustic vibrations in a combustion chamber , in particular in the combustion chamber of a gas turbine, comprising a Helmholtz resonator . having a resonator space and a connecting tube by means of which the resonator space is connected to the combustion chamber , characterized in that the Helmholtz resonator is equipped with first means for controlling the resonator frequency as a function of the frequency of the combustion-chamber vibrations.

2. Apparatus according to Claim 1, characterized in that the first means comprise second means for controlling the density of the gases located in the connecting tube .

3. Apparatus according to Claim 2, characterized in that the second means control the density of the gases located in the connecting tube by changing the temperature.

4. Apparatus according to Claim 3, characterized in that the second means comprise an electric heating element by which the gases located in the resonator space can be heated.

5. Apparatus according to Claim 3, characterized in that the second means comprise a scavenging-air feed line which leads into the resonator space and by means of which scavenging air can be directed through the resonator space .

6. Apparatus according to Claim 5, characterized in that a control valve is provided for controlling the scavenging-air feed in the scavenging-air feed line .

7. Apparatus according to either of Claims 5 or 6, characterized in that, to improve the thermal coupling of the resonator space to the combustion chamber , the connecting tube projects with a tube piece into the combustion chamber .

8.   Apparatus according to Claim 3, characterized in that the second means comprise an electric heating element   by which the gases located in the connecting tube   can be heated.

5 9.   Apparatus according to one of Claims 3 to 8, characterized in that the resonator space   and/or the connecting tube   is surrounded with thermal insulation   ....

10.   Apparatus according to Claim 2, characterized
10 in that the second means comprise a gas feed line which leads into the resonator space   and by means of which gases of different density can be directed alternatively into the resonator space · ..

11.   Apparatus according to either of Claims 4 and
15 8, characterized in that, to prevent the ingress of hot gases from the combustion chamber   : into the resonator space   , shielding air   is blown from outside into the connecting tube   .

12.   Apparatus according to Claim 2, characterized
20 in that the first means comprise a control circuit which controls the density of the gases located in the connecting tube . . in accordance with the phase difference between the combustion-chamber vibrations and the resonator vibrations.

25 13.   Apparatus   according   to   Claim   12, characterized in that the control circuit comprises at least · one   pressure   sensor   each in   the combustion chamber   and the resonator space   , downstream measuring transducers   , a phase
30 comparator _ , and an activating unit   · .

14.   Apparatus for damping thermoacoustic vibrations in a combustion chamber substantially as herein described with reference to any of figures 1 to 4 of the accompanying drawings.

The Patent Office

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Application No: GB 9506413.5	**Examiner:** Robert L Williams
Claims searched: 1-14	**Date of search:** 27 June 1995

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

   UK Cl (Ed.N): F4T (TAM1)(TAM2)(TAX1)(TGS)

   Int Cl (Ed.6): F23M 13/00

Other: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	WO 93/10401 A1 Siemens	1
A	US 3,840,326 R E Schreter	1